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A STUDY OF URBAN STORMWATER MANAGEMENT AND WATERLOGGING CONTROLLING BASED ON INTERNET OF THINGS

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ABSTRACT

Every year, there are a lots of cities that have water flooded or waterlogging problem in China. At the same time, the world is facing a challenge of water shortage. Therefore, a study of stormwater management system aimed at effective and scientific usage of stormwater resources will process progress of urban stormwater management greatly, also is of great significance to the cities' development. This paper focused on analyzing the present situation of urban stormwater management and waterlogging prevention among domestic and foreign cities, introduced the technology of Internet of Things for the design of urban stormwater and waterlogging control system. Integrated the urban water demand forecasting model in the field of application, used Artificial Neural Network Model of Error Back Propagation Algorithm to establish a prediction model in order to help the administrator make better decisions while running the stormwater management system. Through the simulative trainings and experiments, the experimental results indicate that the numerical error of predicted value shows a downward trend, and it gradually tends to its true value.

KEYWORDS: Urban stormwater management; waterlogging controlling; Internet of Things; water demand forecasting.

1. Introduction

The Bulletin of Flood and Drought Disaster in China 2014 released by the Ministry of Water Resources of China shows 1621 counties (including cities and districts) in 28 provinces (including autonomous regions and municipalities) in China was affected by flood disaster in 2014, and 125 cities of them suffered from water flooded or waterlogging. The direct economic loss hit 157.355 billion RMB. At the same time, China and even the whole world are facing a challenge of water shortage. Rain water is one of important components of natural weather and water resources, so it has a certain amount of predictability. Stormwater has both positive and negative effects to the development of urban economy. It can be used to supplement and improve the amount of water resources in the city, and it also could be a total disaster threatening the safety of the city. With the rapid development of cities, the great increase of the proportion of the urban impervious pavement and urban population, a long-term Heat Island Effect gradually emerge in cities. It strengthened the thermal convection of the atmosphere above the city and accelerated the formations of convective cloud and convective rainfall with a manifestation of disastrous rainfall companied by hail and storm. Therefore, a study on stormwater management system aimed at effective and scientific usage of stormwater resources and efficient process of urban stormwater management will be of great significance to the cities' development.

2. The present situation of the urban stormwater management and waterlogging prevention

2.1 The present situation of stormwater management and waterlogging prevention in Chinese cities

Waterlogging prevention in China started early. Small reticulate drainage system has emerged in certain areas of China since the Shang Dynasty. At present, the urban stormwater management mainly relies on the river and underground drainage pipe network. The urban drainage pipe network system is an important urban infrastructure to gather and transport urban stormwater and sewage, undertaking an important responsibility of the urban flood control and drainage. The modern stormwater management and waterlogging prevention system in China is in slow development, currently merely in consideration of flood control and drainage, without the consideration of the stormwater treatment and recycle. From theory, the traditional concept of urban stormwater management in China basically includes urban stormwater pollution control, urban stormwater storage, stormwater recycle in buildings, etc. The innovative concepts mainly includes building a hierarchical stormwater management grid, designing a comprehensive and overall engineering measure, identifying and key planning the key points of the process of stormwater management to accomplish stormwater infiltration and stranded resources reuse, etc.

It can be seen that the shortcomings of the urban stormwater management in China mainly are insufficient consideration of the diversity of water system and the improper use of the stormwater resources.

2.2 The present situation of urban stormwater management and waterlogging prevention in foreign cities.

The main measures and development trend of urban stormwater management and waterlogging prevention in foreign cities are as follows:

United States: statistical nanlyze of the actual situation of urban stormwater, and then build a grading drainage system, large underground water reservoirs and green buildings according to the actual conditions of the stormwater, which turns the pattern of stormwater management from "drainage-oriented" to "infiltration and storage-oriented".

Germany: start to use a new urban stormwater management system of "depression-seepage drainage system". This system includes onsite installations of depressions, seepage canal and other facilities. These facilities are connected with the holed drainage pipes and develop into dispersed stormwater management systems. Through a short-term storage in the low-lying meadows and long-term storage in the seepage canals, these facilities ensure as much infiltration of stormwater as possible. The system represents a new concept of "runoff and zero growth" in drainage system design. The stormwater management is turning from "water drainage" to "water recycle". The measure of stormwater management is changing from single-function to multi-functions.

Britain: Sustainable Urban Drainage Systems (SUDS) is a new approach. Under the overall consideration of urban drainage system, it introduces the concepts and measures of sustainable development, with proper consideration of the water flow, water quality and environment, solves the problems of surface water drainage. Its engineering facilities include infiltration ponds, underground seepage canals, permeable pavements, controlled stormwater outlets, ponds and small reservoirs, etc. The concept of SUDS is turning from the on-ground development to the under-ground development, and from the one-way stormwater control to the cricoid stormwater control. Singapore: rebuild low roads, build regional flood-control walls and green buildings. It is a combination of waterlogging controlling and landscape construction

New Zealand: enlarge the capacity of the drainage pipe network; increase the number of the stormwater storage facilities and expand the utilization of urban stormwater. level of practical applicationIt can be seen that the approaches of stormwater management and waterlogging control in foreign countries mainly lie in the following: the large-diameter pipeline makes the drainage system run more smoothly and it delays the peak flow of stormwater; reservoirs can increase the flood storage space and prolong the time of stormwater storage, ease the pressure of the drainage of downstream river.level of the Internet networkStormwater infiltration can play a "soil reservoir" regulative capacity of storage, and reasonably increase the amount of groundwater recharge in both deep and shallow levels, reduce surface runoff filling.level of Perception Sensor

3. The design of urban stormwater management and waterlogging controlling on the basis of Internet of Things.

3.1 The Internet of Things Technology

Based on the Internet, the Internet of Things increases a sensor network layer of the network technology. It can make connection between one object and another to achieve an "Object-Object" communication, and finally realizes the intelligent recognition, positioning, monitoring and management. The structure of the Internet of Things is shown in figure 1, including three levels:

① The level of Perception Sensor: use RFID, sensor, two-dimensional code and other equipments and technologies to collect the relevant information and data of objects in real time.

② The level of Internet network: use the Internet network which is consisted of a variety of network connecting devices and circuits to transmit the real-time and accurate data collected by the level of Perception Sensor.

③ The level of practical application: According to the actual function demands in various application scenarios, design application software to process the data transmitted from the network layer of Internet, in order to realize the functions of practical application of intelligent monitoring and intelligent management, etc. The Internet of Things can be widely applied in industrial control, environmental monitoring, urban management and many other fields.

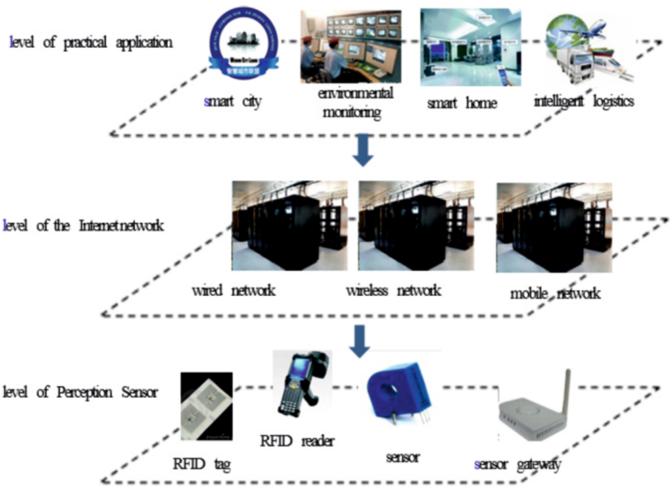

Figure 1 The structure diagram of the Internet of Things

3.2 The design of urban stormwater management and controlling system on basis of the Internet of Things.

3.2.1 The structure diagram of urban stormwater management and controlling system.

The urban stormwater management and controlling system on basis of the Internet of Things is shown in figure 2, it consists of three parts:

① Sensor network composed of sensors. It installs sensor in the node position to monitor the real-time data of stormwater quantity, flood flow, flow of stormwater pipe network, stormwater pressure and the status of valve, etc. The wireless sensor network adopts Zigbee protocol, Zigbee terminal equipment, Zigbee repeater and Zigbee coordinator these three kinds of nodes ' hardware to build MESH network topology. The basic data collected by water distribution network from the field includes: pipe segment information, node water flow, the information of water source and water pump, the water supply of water plant, water consumption of user, valve opening and the information of monitoring sites, etc.

② The Internet network composed by network connection equipments and transmission lines connects each nodes' sensor by Internet to achieve the real time data transmission. Zigbee is a short-rang wireless networking technology in recent years. It has the characteristics of low cost, low power consumption, strong ability of self-organizing and self-recovering, etc.

③ On the level of the application of stormwater management and control, each monitoring site collects monitoring data through the sensors, and transmit data to the stormwater management and waterlogging control center through the intermediate routing nodes of the Internet. The center will analyze, process and forecast the data and then generated a decision-making program. Therefore, the system of stormwater management and waterlogging control of the Internet of Things mainly integrated an urban water demand forecasting model for achieving the aided scheduling decisions of the stormwater management system.

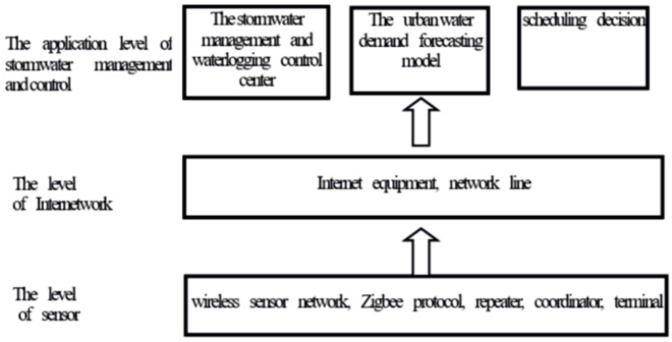

Figure 2 The structure of stormwater management and control system

3.2.2 Urban water demand prediction model.

Urban water demand prediction refers to the comprehensive consideration of urban historical water consumption data, as well as the city's total industrial output value, per capita income, population, repeating utilization factor of water, urbanization rate, the amount of water consumption generating per 10000 RMB GDP , annual precipitation, green coverage area and all sorts of effecting factors. It analyze the development of urban water demand and the change rule, and predicts the urban future water demand. It is a kind of complex analysis process.

This paper uses the model of BP (Back Propagation) artificial neural network toestablish a prediction model of urban water demand. The nodes of the BP neural network are divided into three categories: the input node Ni, invisible node Nj, the output node No. The connecting weight between the input node and the hidden node is CWij, and the connecting weight of the hidden nodes and output nodes is CWoj. When the expected output node is to, the calculation process of the model is as follows:

Step 1: Forward-propagation. Use the input value to calculate the corresponding output value, based on the threshold value to control the artificial neuron activation value of hidden level. The output of the hidden node is

Step 2: Back Propagation. Usually, there is an error between the one-time inputted output value and actual value. Use BP to correct the numerical error: starting from the output level to the hidden level, then to the input level, to correct the connection weights and threshold of each level step by step.

Step 3: Circuit Training. Circuit training is the repeated procedure of input forward propagation and Error Back Propagation to make the neural network remember the training mode and reduce the numerical error of output.

Step 4: Interpretation of results. Each time, after the completion of circuit training, the neural network will make interpretation of the results. If the amount of training has reached its limit or the standard errors, the learning process will stop or if not, continue the training.

Above all, the BP neural network model of training steps flow chart be shown in figure 3:

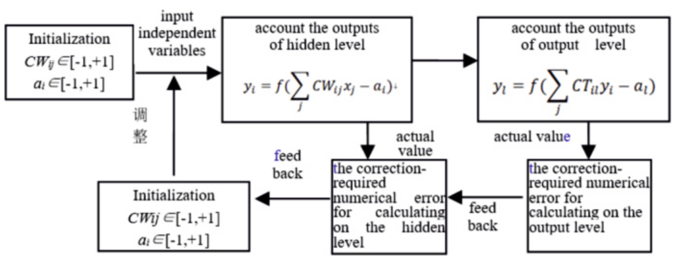

Figure 3 the flow chart of training steps in BP neural network model

3.2.3 The Analysis of Prediction Result

Upon the training sample of the data of 2001-2010 in Y city, the test sample of the data of 2011-2014, the input variable of the driving factor, and the output variable of the water quantity, to run trainings and testings, the results are shown in table 1. It can be seen from the results that the predicted value relative error shows a downward trend, and gradually turns to the real value.

table 1 Urban water demand prediction data of 2001-2010 in Y city

Year	Real value/100 million m3	predicted value/100 million m3	relative error
2011	92.7362	98.1368	5.46
2012	95.3235	99.5912	6.52
2013	96.3160	92.4121	4.72
2014	96.8278	94.3656	2.61

4. Conclusion and prospect

This paper analyzes the significance of stormwater in urban flood and urban development. Targeting the problems of insufficient consideration for diverse water contribution to drainage system in the urban stormwater management in China, and the improper utilization of the stormwater resources, it analyzes the current situation of stormwater management and waterlogging control in foreign cities. Through case study of the application of the "depression-seepage drainage system" stormwater management system in Germany, and the sustainable drainage system in Britain, it arrives at a conclusion that the stormwater management and waterlogging control in foreign cities mainly lie on new approaches, such as large-diameter pipeline, reservoir, stormwater infiltration (playing a role of "soil reservoir" storage).

With the introduction of the technology of the Internet of Things, the design of the urban stormwater and waterlogging control system, the construction of architecture on sensor level, internet level and the application level in stormwater management and control system, this paper establishes a prediction model of urban water demand on the application level. Using the BP (Back Propagation) artificial neural network model, it establishes a prediction model which assists to make scheduling decisions in the stormwater management system.

Finally, upon the experiment data of 2001-2014 data in Y city, the input variables of the driving factors and the output variable of the water consumption, to run trainings and testings, the results indicates that the numerical error of predicted value shows a downward trend, and gradually turns to its true value. In conclusion, the artificial neural network model based on the BP (Back Propagation) can master the trend and key influencing factors of urban water consumption more accurately, and lay a stable premise and foundation for the reconstruction and optimization of urban water supply pipe network system.

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